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JPRS L/10368

4 March 1982

# Worldwide Report

TELECOMMUNICATIONS POLICY,  
RESEARCH AND DEVELOPMENT

(FOUO 4/82)



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WORLDWIDE REPORT  
TELECOMMUNICATIONS POLICY, RESEARCH AND DEVELOPMENT  
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JAPAN

BRIEFS

NTT POLICY ON SATELLITES--Tokyo, 16 Feb (JIJI Press)--The quasi-governmental Nippon Telegraph and Telephone Public Corp. (NTT) has fixed its policy of orbiting its large-capacity communications satellites using the space shuttle of the U.S. National Aeronautics and Space Administration (NASA). Japan's communications satellites for practical use have hitherto been launched using domestically-produced rockets. NTT, the nation's telecommunications monopoly, will seek approval of the Space Development Council before making a final decision on this score. Under NTT's plans revealed so far, it will blast off a one-ton communications satellite with a capacity of 25,000 telephone circuits in fiscal 1988 and a four-ton satellite with a capacity of 100,000 circuits around fiscal 1992. Japan's fiscal year starts in April. NTT also plans to link via these satellites telephone stations exclusively for long-distance calls to be set up in each prefecture by putting up antennas of four meters in diameter on the roofs of these stations. Another factor behind NTT's emerging policy of launching large-capacity communications satellites is its strong wish to advance into data communications business. [Text] [OW161451 Tokyo JIJI in English 1436 GMT 16 Feb 82]

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INTER-AFRICAN AFFAIRS

APTU FAVORS AFSAT SATELLITE FOR 1985-1994

Paris AIR ET COSMOS in French 16 Jan 82 pp 34-36

[Article by Pierre Langereux: "For a Regional Telecommunications Satellite in Africa--The Countries of the APTU (African Postal and Telecommunications Union) in Favor of an 'AFSAT' Satellite for 1985-1994"]

[Text] The study carried out, under the aegis of the Eurospace group, by a European consultant group comprising Satel-Conseil, the ITM [Modern Industries and Techniques] company and the Bureau Yves Houssin, concerning "the telecommunications and radio-television needs of the 13 Francophone member countries of the APTU<sup>1</sup> and 4 neighboring countries<sup>2</sup> capable of being fulfilled by a satellite during the period 1985-1994," has shown that a regional telecommunications satellite could be effectively useful to a good number of countries of the APTU.

The situation of the 17 African countries concerned by the study (as well as that of the other countries of Africa, for that matter) is characterized by two dominant traits: low GNP per inhabitant (Fr 1,000 to 2,400), and disturbing underequipment. According to Mamadou Simporé, secretary general of the APTU, "for more than 50 million inhabitants (including Chad) of the APTU member countries, there were in 1980 only 110,000 direct-exchange telephone lines, or about 1 line per 500 population!" Moreover, this insufficiency reflects some striking inequalities. As regards the APTU, nearly 80 percent of telephone subscribers are in the capitals, with the rest distributed among a few large cities; but there are practically no telecommunications facilities in the rural localities and even fewer in the surrounding countryside. In addition, the existing lines are subject to a variable, but always high, rate of unavailability.

The satellite may obviously appear ambitious, even extravagant, in such a context. Actually, it is not so at all, Mamadou Simporé states, for three principal reasons: the satellite is the only feasible means of transmission in Africa, it is less expensive than the other transmission means, and it can only have a considerable effect on the underequipment situation of the African continent.

1. Benin, Central African Republic, Comores, Congo, Ivory Coast, Djibouti, Upper Volta, Mali, Mauritania, Niger, Rwanda, Senegal and Togo. Chad, a member of the APTU, did not participate in the study.
2. Zaire, Ghana, Kenya and Sierra Leone.

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Study of Needs

The Eurospace study, carried out in close coordination with the APTU secretariat and the African national administrations in the AFSAT group, began with a broad study of the needs of the countries concerned and the development they have planned. Thus, the consultants evaluated the entirety of the telecommunications and radio-television needs of each country, and then they estimated the proportion of service that could reasonably necessitate a satellite rather than conventional telecommunications means (radio waves, cables, etc).

The needs were divided into three categories: international and national (inter-urban) public telecommunications, audio and video broadcasting, and telecommunications in the rural environment--these last being distinguished from interurban telecommunications for functional reasons.

The domestic situation of the countries was evaluated in terms of four equipment levels: good, poor, or nonexistent network connection, or no network (the most common situation). The first two cases relate to national interurban connections, and the third and fourth, to rural connections.

For international telecommunications, the calculation of the traffic and the number of international circuits took account of all the APTU member countries as well as Cameroon, Gambia and Zaire. The assumptions made are an average annual increase for the whole of the countries' international connections, but varying with the period considered (15 percent from 1979 to 1990 and 12.5 percent thereafter). Particular stimuli toward modifications of routing, transmission and general operation were also envisioned. Finally, for distribution of traffic as between earth and space facilities, the study adopted the following criteria: routing of traffic to regional satellite on demand assignment, and 100-percent direct point-to-point connections via satellite when the existing infrastructure is weak, or only 25-percent by such connections when there is radio or underwater cables.

For national telecommunications (not including rural), calculation of the circuit needs was based on a spatial-temporal estimate of the subscriber demand and on traffic forecasts, and a proposal for a distribution between satellite and earth facilities resulted. All localities that have telephone service or are to have it between now and 1985 were taken into consideration. For the period 1985-1994, there was close coordination with the national administrations as regards the rates of growth considered in order to adapt them to each country, sometimes with growth rate differentiated as between the capital and the provinces. The number of telephone circuits anticipated for needs other than telephony were estimated at an overall 5 percent of the number of channels expected for public service. These circuits will be for telegraphy, leased circuits, new services (teletyping, data-transmission, etc) and for replacement of certain private networks that have now reached saturation.

An estimate of traffic distribution was made in function of distances, with the existing facilities taken into account. When there are modern facilities (cables, radio) between two localities, it was supposed that 75 percent of the circuits would go by satellite beyond a distance of 500 km; 50 percent for distances of 100 to 500 km; and that below 100 km, there would be no circuits via satellite. On the other hand, when there are no modern facilities, all circuits would go via satel-

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lite--in all countries--beyond a distance of 100 km. Another hypothesis grouped the countries into three categories for the distribution as between earth and space facilities, with a heavier weighting than before as regards the criteria other than economic. This leads in particular to a more precise assignment of the distributions in terms of the distances.

For telecommunications in the rural environment (defined as the regions not presently served by the national telecommunications network), two types of installation are envisioned: in a locality for public service, and providing service to all the inhabitants; or in the countryside, mainly for the benefit of the farmers. The installation strategy is the planned to have two phases: first of all, installation of network access points consisting of a "rural communications office" equipped with a telex and telephone, and possibly a community TV center; and next, extension of service to subscribers who might increase the profitability of the system, with more rural offices added, creation of small local networks, and installation of networks in the countryside. The total operation (the two phases) would be over a period of 5 to 7 years.

The forecasting of rural telephone traffic was done by two methods. The basic hypothesis considers maximum geographical service at the lowest cost, the objective for 1994 being the serving of 1 percent of the rural population residing in the localities concerned, with doubling of use over a 10-year period (1985-1994). Complementarily, a survey was made of the needs for the entirety of the rural zones of each APTU country as of 1994.

## Total APTU Half-Duplex and Via-Satellite Circuit Needs

Telephone Half-Duplex Circuits	1985		1994	
	Total	Via Satellite	Total	Via Satellite
International	600	400	1,300	1,000
Interurban*	9,600	4,200	19,999	8,400
Rural	<u>5,200</u>	<u>1,900</u>	<u>31,000</u>	<u>11,000</u>
Totals	15,400	6,500	51,300	20,400
Radio-Television	2 to 8 TV programs 10 to 20 FM-radio programs Special service channels			

\* [Source gives no note relating to this note reference.]

It is proposed to meet the rural telecommunications and television needs mainly by satellite, except in the small-size countries. This would lead, as from 1985, to a community telecommunications and TV service, in the proximity of a station installed in each locality, and in 1994, to a distribution of the preceding service to the other subscribers of the locality (by wire) and to those located outside (by radio-telephone).

For audio and video broadcasting, the estimation is more difficult to make. The countries were divided into two categories. Those that have already chosen to transmit radio-TV programs via satellite--by means of a leased repeater on an In-

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telsat satellite--are obviously in a very good position for extension of coverage by way of an African regional satellite. For the large countries that do not presently have a sizable radio-beam infrastructure, the satellite represents the most effective means (in terms of cost and speed of service) for providing coverage of the country. But this assumes a complementary equipment effort (earth transmitting station, receiving stations, TV-FM transmitters, community receivers, etc) in order to make the space investment a profitable one. For the countries that already have a radio-beam network that is dense or developing, the satellite obviously seems less attractive. As for other countries of small territory, use of the satellite does not seem justified.

## Conclusions in Favor of the Satellite

The study thus concludes that for the 13 countries of the APTU, the interurban half-duplex-circuit needs come to 9,600 in 1985 and 19,000 in 1994--a 7-percent rate of growth. If Zaire is added, these figures are 11,600 and 23,000 half-duplex circuits, respectively.

The eventual use of a regional satellite for the international traffic among the 17 countries studies (the 13 APTU countries and the 4 neighboring ones) corresponds to a capacity of 400 half-duplex circuits in 1985 and 988 in 1994. As regards national (interurban) traffic, the initial estimates indicate about 4,200 half-duplex circuits in 1985 and 5,900 in 1994, including Zaire. In the case of hypotheses that further favor the ground-based systems, the total number of half-duplex circuits still comes to 2,700.

Concerning rural telecommunications, the total half-duplex-circuit needs of the 13 countries of the APTU was estimated at 5,200 in 1985 and 31,000 in 1994. Including Zaire, these figures are 6,300 and 49,200 half-duplex circuits, respectively. Among these needs, the proportion of rural telecommunications that could go via satellite was estimated at 1,900 half-duplex circuits in 1985 and 11,000 in 1994, which represents an average annual rate of growth of 19 percent. With Zaire, these needs reach 2,500 and 15,700 half-duplex circuits, respectively. This 19-percent growth rate, which may seem high in comparison with the other categories of telecommunications, actually follows from the tremendous rural-telecommunications lag in Africa. The secretary general of the APTU recognizes, in fact, that a start has to be made from nothing in order to try to reach an "acceptable" situation around 1994--one which would still be only a 1-percent telephone density in certain localities and even just 0.5 percent in others!

In the area of radio-television, where extreme infrastructural weakness is also noted, the equipment effort to be made is considerable. But it is presently impeded by the lack of equipment, qualified personnel and financial means. The APTU study concludes that "six countries of Africa--the Central African Republic, Upper Volta, Mauritania, Mali, Niger and Senegal--present very favorable characteristics for use of the satellite for meeting their radio-TV needs, and that two other countries--Congo and Ivory Coast--despite the present or future large size of their radio-beam network, could find use of a satellite an attractive alternative for development of their TV-FM radio network." On the other hand, the APTU study recognizes that the other five countries--Benin, Comores, Djibouti, Rwanda and Togo--could solve their radio-TV network problems without recourse to the satellite.

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Such are the results of the study approved by the Council of the APTU at Lome in August 1981 and presented publicly for the first time at the recent Eurospace International Conference by Mamadou Simporé, secretary general of the APTU.

These data now constitute the basis for new complementary studies recently ordered from Eurospace, both by the APTU and by the Pan-African Telecommunications Union (PATU), in liaison with the African National Radio-Television Union (URTNA). One of the studies, for which a contract of Fr 2 million has been made, is an extension to the scale of the PATU--which incorporates all the countries of Africa (including those of the APTU)--of the telecommunications-needs study previously carried out by Eurospace. The other is a parametric study concerning the feasibility of an AFSAT satellite system covering the needs of the APTU and eventually those of the PATU also. This second study is presently financed to the extent of Fr 3 million by the European Development Fund (EDF), but supplementary financing is expected from France, Italy and Great Britain, to reach the Fr 8 million needed for carrying out the work. These new studies will be conducted under the direction of the European Eurospace group, with the participation of the European Space Agency (ESA), the ITM company and the French National Center for Telecommunications Studies (CNET), as well as with the GTS (Great Britain) and Consultel (Italy) companies.

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ZAIRE

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AGREEMENT WITH BURUNDI--Zaire/Burundi agreement on telecommunications. The government of the Republic of Burundi and the Executive Council of the Republic of Zaire signed a formal agreement on telecommunications at Bujumbura on 11 December. The purpose of the agreement is to set up and operate a direct telecommunications link between the two countries for telegraphic services, telex, rented circuits, facsimile, data transmission and radiophototelegrams using available and future technology. [Text] [Paris MARCHES TROPICAUX ET MEDITERRANEENS in French No 1886, 1 Jan 82 p 39] [COPYRIGHT: Rene Moreux et Cie Paris 1982] 9855

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ZIMBABWE

BRIEFS

COOPERATION WITH ROMANIAN NEWS AGENCY--Salisbury, 25 Feb (PL)--Representatives from the News Agencies of Zimbabwe (ZIANA) and Romanian (AGERPRESS) signed in this capital an agreement for the exchange of information. The agreement was signed by the chairman of the amalgamated mass media of Zimbabwe Davison Sadza and the Romanian ambassador to this country Petre Blajovici. Sadza said he hoped the signing of the agreement would go a long way to improve the relationship between the two countries. In reply Ambassador Blajovici said the signing was a new step forward to improve cooperation between the two countries. [Text] [PA242130 Havana PRELA in English 2020 GMT 24 Feb 82]

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ITALY

MICROPROCESSOR APPLICATIONS IN TRANSMISSION SYSTEMS

Turin ELETTRONICA E TELECOMUNICAZIONI in Italian Nov-Dec 81 np 241-246

[Article by M. Calabrese, M. De Bortoli, G. Panarotto, G. Rocca and E. Thomas\*]

[Text] Summary--Microprocessor applications in transmission systems. This paper illustrates the reasons in favor of the use of microprocessors in telecommunications transmission systems. After an overview of the possible fields of application of these devices, together with the advantages and the compromises for a profitable insertion within the complete system, some applications in experimental plants are described. In a modem for digital transmission at 140 Mbit/s rate, the microprocessor controls several fundamental parameters; in another application it implements a new equalization algorithm and in a field trial (COS 3/FOSTER) it collects the significant link parameters and processes them for the overall system behavior monitoring. A forecast is also presented on future developments of these applications.

1. Introduction

Many applications have been found for microprocessors in the telecommunications field, especially within the framework of switching installations.

Their introduction into transmission systems has been less immediate, though, mainly for two reasons: the analog nature of the signal to be treated, and the high frequencies involved.

The digital transmission systems offer greater possibilities for insertion of microprocessor devices, since treatment of the signal is required at discrete instants--that is, the instants at which the decision is made.

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\* Dr of Engineering Mario Calabreses, p.i. [expansion unknown] Marco De Bortoli, Dr of Engineering Gianfranco Panarotto, p.i. Giovanni Rocca, p.i. Ernesto Thomas, of the CSELT (Telecommunications Research and Study Center), Turin.

Typescript received 23 July 1981.

This paper was presented to the annual Congress of the AICA [Italian Association for Automatic Calculation] at Pavia, 23-25 September 1981.

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Within this framework, two types of application have been individuated, distinguished essentially by the different ratio between the processing speed of the microprocessor used and the speed of transmission of the symbols:

- 1) processing of the signal in real time, for transmission systems of sufficiently low speed;
- 2) management of the equipment through processing of statistical magnitudes and of significant signals at low speed, both through control of algorithms and through monitoring of the system's performance characteristics.

These two aspects are discussed in detail in this paper. Several sets of equipment built in the CSELT are described. For each of them, the purpose and the type of processing done on the signals are presented.

From the applications described, the advantages that can be obtained through this type of approach are obvious, especially for experimental projects: for example, the considerable flexibility in the various tests, because of the possibility of doing things through mere changes of the software.

## 2. General Considerations on the Use of Microprocessors in Transmission Equipment

The use of microprocessors in transmission equipment, in place of analog circuits or the traditional logical circuits, is justified when one of the following conditions occurs:

- a) real-time processing of the signal is very complex and must be done with a low-speed data flow. In this case, use of a microprocessor considerably simplifies the hardware of the equipment, requiring from the software a part of the functions that have to be carried out;
- b) the problem arises of monitoring functional blocks of the transmission equipment, through development of algorithms on low-speed signals, or of keeping the performance characteristics of such apparatuses under control. In such case, in addition to the advantages cited in paragraph a), use of the microprocessor gives the control or management structure considerable flexibility, this being an especially useful characteristic when experimental equipment is developed.

Attention is now drawn to the two peculiar characteristics of microprocessor architecture: modularity of the hardware and flexibility of the software.

Current technology makes available a considerable number of components, capable of carrying out complex and specialized operations, that can be inserted into microprocessor systems as peripheral equipment on the system buses.

Several components of special importance in transmission systems can be taken as examples. Analog-digital (A/D) and digital-analog (D/A) converters, which make it possible to digitalize analog signals and restore the processing results in analog form, are the necessary interfaces between the microprocessor and the system.

In addition, if the processings are rather complex from the mathematical point of view, it is possible to insert into the system a multiplier or arithmetical processing unit capable of carrying out the fundamental arithmetical operations autonomously, even on numbers expressed in floating point, and of doing the conversions between that format and the entire format.

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A single well-organized system is therefore easily expandable, from the hardware point of view, to meet the individual requirements and adapt the structure to new situations that may arise from time to time in the experimentation.

As for the software, its task is to receive the signals and process them. Through program changes, it is possible to modify the algorithms, while by modifying the data it is possible to vary the static parameters of the problem, thus adapting the program to the specific application in the best way.

In cases in which the processing of the signal has to be especially fast, it is advisable to use bipolar microprocessors of the bit-slice type instead of the more usual microprocessors built with MOS [Metal-Oxide Semiconductor] technologies.

This choice has an effect on both the hardware and the software. The user does in fact have to construct both the central unit on the basis of the individual components and the set of instructions most appropriate for the application on the basis of the elementary operations of logical-arithmetic type defined within the individual components (microinstructions). The set of instructions is defined by the user by accurate analysis of the algorithm to be developed and isolation of the most elementary and repetitive steps.

This approach may prove considerably burdensome in cases where support instruments are lacking, both for development of the software and for the checking-out of the system; nevertheless, the advantages obtained in terms of processing speed are notable.

## 2.1. Processing of the Signal

Some of the main considerations relating to transmission of the signals are digital filtering, adaptive equalization, the algorithms for extraction of the synchronisms, estimation of channels not known beforehand, and coding and decoding operations.

These functions, usually carried out in analog mode or with dedicated logic, are carried out by means of logical and mathematical operations done on the flow of the signal samples taken at the symbol-transmission speed.

One therefore thinks immediately of the possibility of doing these operations with microprocessors. There is, however, a limitation in their use for these purposes, due essentially to the reduced processing speed as compared with the transmission speeds usually used. The basic cause of this limitation lies in the complexity of the algorithms and in the mass of data to be treated, which necessitate use of microprocessors for processing signals whose transmission speed does not exceed some 10 kHz.

In order to partly overcome that limit, it is possible to construct microprocessor architectures in which each processor is dedicated to the carrying-out of a single function, with considerable advantages in overall processing speed and therefore with the possibility of application to systems of higher transmission speed.

In Chapter 4, there is described in detail, as an example of real-time processing of the signal, a nonlinear equalizer of the "Decision Feedback and Feedforward" type (Bibliography 2).

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The high number of processings to be done, which is connected with the necessity of a certain speed of the data-flow to be treated, required the use of a microprocessor of the bit-slice type.

It is interesting to note that this arrangement fully met the expectations as regards the flexibility of its use: it was in fact possible, solely with modifications of the software, to test the algorithm in various conditions of number of cells and parameter values. It was also possible--again, solely with variations of the software--to achieve a transverse linear equalizer for the purpose of comparing the performance characteristics of the two equalizers.

## 2.2. Management and Control of the Systems

A different class of microprocessor applications is the processing of the statistical parameters connected with the information signal. Examples of these statistical magnitudes, which were used in the systems illustrated later, are the mean quadratic error and the average of the absolute values of the error encountered in the decision-making organ.

By optimizing these magnitudes, it is possible to control several parameters of fundamental importance in the system, such as the coefficients of the adaptive equalizer, the optimal phase for signal-sampling, the phase of the demodulator--for example, in AM-SSB (Amplitude Modulation - Single Side-Band) systems that require coherent demodulation.

The statistical magnitudes referred to above can be obtained with dedicated circuits or by making use of the microprocessor's processing capacities.

In the former case, the magnitudes are calculated by the external circuits using the in-line signals and are transferred to the microprocessor at lower speed. In the latter case, they are generally determined by using a data flow obtained by sub-sampling of the in-line signal.

The experimentation done demonstrates that statistical magnitudes calculated in this way are equally significant for controlling the system's parameters, provided that the time interval of their integration is suitably chosen.

In both cases indicated above, the microprocessor is asked to perform the task of minimizing the statistical function, in accordance with the optimization algorithms best-adapted to the situation in question, of establishing the values of the parameters under control, and as the case may require, of furnishing indications of correct system functioning to a local operator.

In Chapter 3 is presented a transmission system, at the rate of 140 Mbit/s, that uses the microprocessor for management of the receiving terminal. The microprocessor is used for control of the process of adaptation of the coefficients of the transverse equalizer that has to compensate for the cable distortions, for controlling the decision thresholds and for recovery of the optimal sampling instant.

Use of the microprocessor has proved especially advantageous because it has given the designers considerable experience on the validity and the limits of all the alternatives examined, testing them directly in the installations in real conditions and not only by computer simulation of them.



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A final field of use of this type of device is general monitoring of the correct functioning of the system and of its performance characteristics. For such purposes, the microprocessor does not have to have special speed characteristics but only suitable peripheral equipment capable of collecting the magnitudes to be examined and providing them to the user in the most appropriate form, and, as the case may call for, transmitting them to collection and supervision centers, as in the remote monitoring systems, for example.

Microprocessors offer the advantage of being able to coordinate collection of the most significant data on the proper functioning of the system and do the processing of them, thus furnishing a complete and organic picture of the parameters to be monitored and facilitating recognition of causes of malfunction.

This methodology is especially useful in the perfecting of experimental systems and in characterization of them.

In Chapter 5 is presented, as an example of this approach, the system for acquisition and processing of the measurement data of the experimental optical-fiber transmission installation COS 3/FOSTER. In this system, which has the task of relating deterioration of transmission quality to the performance characteristics of components of fundamental importance, it has been possible to distribute the processing capacity to the individual terminals that are geographically dispersed, thus decentralizing the monitoring and treatment of the magnitudes measured and reserving to the centralized control unit the job of gathering and correlating the data.

### 3. Microprocessor Inserted into the Hybrid-Type 140 Mbit/s Digital Transmission System

#### 3.1. Objectives of the Application

The microprocessor application concerns adaptive control of the multilevel receiving terminal of the "hybrid"-type 140 Mbit/s digital transmission system developed in the CSELT (Bibliography 1).

This system provides for the insertion, between two digital regenerators, of a number of analog repeaters that only make it possible to recover the attenuation introduced by the cable into the useful signal band (Figure 1): the effects of dis-equalization of the signal and of the related variations accumulate along the sections of analog repetition falling between two digital terminals.

It is therefore necessary to provide, for a high number of sections, an adaptive-control device that makes it possible to recover the variations of the system's characteristics in time, maintaining satisfactory and constant transmission quality.

For this purpose, the microprocessor device inserted into the receiving terminal (Figure 2) examines the signal received, taking a sample out of every 1,000, and calculates an error function (EF)\*, by minimizing which it controls:

---

\* The EF is defined thus:  $\frac{1}{N} \sum_{i=1}^N |l_i - l_{ri}|$ , in which  $l_i$  is the level of the symbol received,  $l_{ri}$  is the relative reference level, and  $N$  is the base of integration of the error function.

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- 1) the phase of sampling instant  $\phi_T$ ;
- 2) the values of the decision thresholds;
- 3) the coefficients of the adaptive transverse equalizer (ETA).

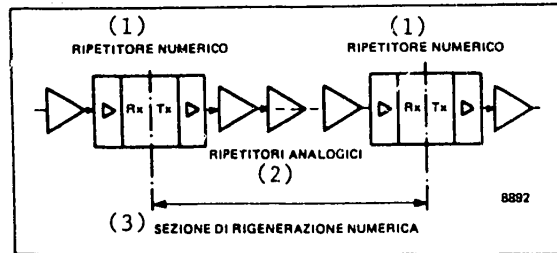


Figure 1. Block diagram of the hybrid transmission system

Key:

1. Digital repeater
2. Analog repeaters
3. Digital regeneration section

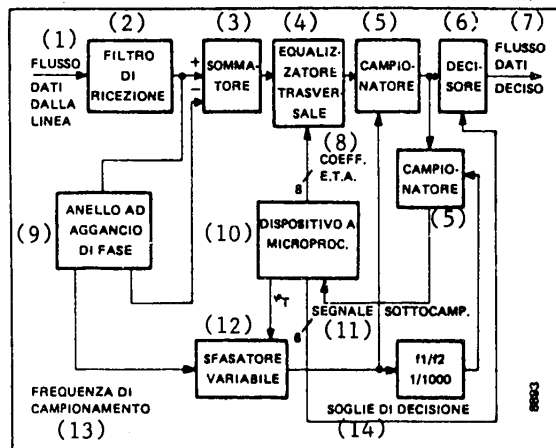


Figure 2. Block diagram of the receiving terminal of the 140 Mbit/s system

Key:

- |                         |                            |
|-------------------------|----------------------------|
| 1. Data flow from line  | 8. ETA coefficient         |
| 2. Reception filter     | 9. Phase-lookup ring       |
| 3. Adder                | 10. Microprocessor         |
| 4. Transverse equalizer | 11. Signal subsampled      |
| 5. Sampler              | 12. Variable phase-shifter |
| 6. Decider              | 13. Sampling frequency     |
| 7. Data flow decided on | 14. Decision thresholds    |

## 3.2. Reasons for Adoption of a Microprocessor

The device for control of the receiving terminal must carry out logical and arithmetic functions of a certain magnitude, in accordance with algorithms that are computer-simulated, only on the basis of simplified and therefore limiting working hypotheses.

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In the development phase, it is therefore indispensable to be able to make use of a device inserted into the real terminal and making it possible to modify easily both the test algorithms and the parameters relative to them.

A device built with a microprocessor meets these requirements, inasmuch as the hardware structure remains unchanged, while the behavior of the device depends on the content of the program memories (algorithms) and data (parameters). In addition, the various buses (addresses, data, control) existing in the microprocessing structure permit easy connection of the most diverse peripheral equipment, which makes possible rapid execution of measurements, recording, processing and presentation of the data of preeminent interest.

With the algorithms and the relative parameters defined, a simplified device is inserted on the terminal; this device too is built with a microprocessor, both for easy transposition of the original device and because the complexity of the circuit, dimensions, construction time, power consumption and costs are decidedly competitive with those of the alternative analog device built with traditional-logic circuits.

#### 4. Microprocessor for Development of a Nonlinear Equalizer

The application consists in the construction, by means of a microprocessor, of a type of nonlinear equalizer recently designed in the CSELT (Bibliography 2).

This type of equalizer\* unites with the principle of backward reaction of the decisions decided on (decision feedback) the forward reaction of the same symbols (decision feedforward), thus permitting nearly total cancellation of the interfering signals, even in the presence of strongly distorted channels.

The equalizer can be inserted into the receiving terminal of a digital transmission system in accordance with the block diagram of Figure 3.

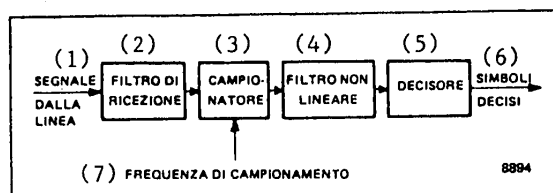


Figure 3. Block diagram of receiving terminal of a digital transmission system with insertion of a nonlinear filter

Key:

- |                     |                       |
|---------------------|-----------------------|
| 1. Signal from line | 5. Decider            |
| 2. Reception filter | 6. Symbols decided on |
| 3. Sampler          | 7. Sampling frequency |
| 4. Nonlinear filter |                       |

\* Patents filed.

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The equalizer considered, the block diagram of which is given in Figure 4, presents two parallel paths: the upper one has the purpose of correcting the precursor of the input wave form, and the lower one, the relative tails.

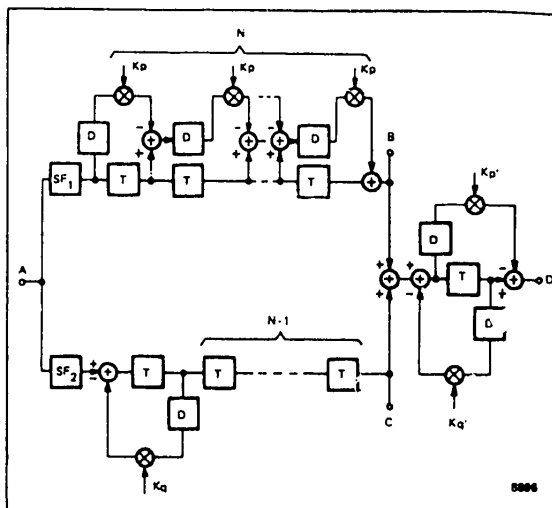


Figure 4. Block diagram of the nonlinear equalizer

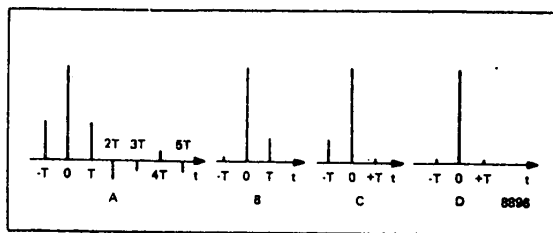


Figure 5. Diagram of the wave forms sampled at the various points of the equalizer

The  $SF_1$  filter is a transverse filter with eight coefficients; it makes it possible to force to zero the interfering signals that are different from the precursor, which will be cancelled by the following cells with decision feedforward, and by the first tail.

The addition of an ever greater number of cells of the decision-feedforward type in cascade ensures a gradually decreasing error probability at the output of the upper branch, since, in the event of a mistaken decision in a cell, the error can be remedied in the succeeding cells. At the output of the upper path (point B), the signal is affected by the residue of the first tail not completely cancelled by  $SF_1$ .

The  $SF_2$  filter too is a transverse filter with eight coefficients and has a role analogous to that of  $SF_1$ ; the residual tail is cancelled by a cell of the decision-feedforward type, and the signal at point C will therefore be affected by a distortion due to the residue of the precursor.

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The signals coming from the two routes flow together into an adder and from there into a double cell with feedforward and feedback reactions that provides for elimination of the precursor signal and the residues tail.

The diagrams of the wave forms sampled at points A, B, C and D are given in Figure 5.

The type of algorithm used and the type of signal worked on lend themselves very well to an arrangement using a microprocessor in which, by exploiting the flexibility of the software prepared, it has been possible to develop the various internal functions of the equalizer and investigate various construction schemes and their relative performance characteristics.

In particular, it has been possible to make a comparison between the performance characteristics of the nonlinear equalizer of Figure 4 (with  $N = 3$ ) and those of the eight-coefficient transverse equalizer of "zero-forcing" type--that is, of complexity equal to that of each of the two shaping filters  $SF_1$  and  $SF_2$ .

From the curves of Figure 6, which indicate how the error rate at the decision point varies with the variance of the signal-to-noise (S/N) ratio at the input of the equalizing structure, it can be noted that the performance characteristics are better in the case of the nonlinear equalizer.

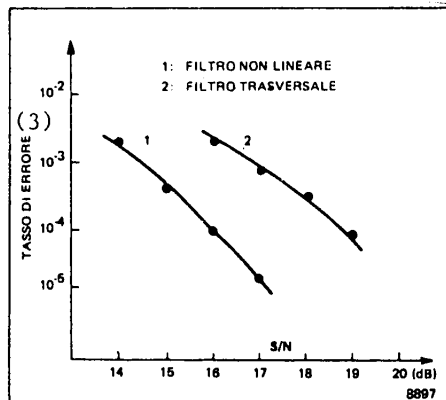


Figure 6. Curves comparing the performance characteristics of the nonlinear equalizer and the transverse equalizer

Key:

- |                     |                      |               |
|---------------------|----------------------|---------------|
| 1. Nonlinear filter | 2. Transverse filter | 3. Error rate |
|---------------------|----------------------|---------------|

#### 5. Microprocessor Inserted into a System for Acquisition and Processing of the Measurement Data of the Experimental COS 3/FOSTER Installation

The application consists in the construction of a microprocessor device whose task is to:

- 1) take the measurement data relative to the significant magnitudes of one or more transmission systems (up to a maximum of eight);
- 2) do several processing operations on them;

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- 3) transmit to a (remote) centralized organ the information put into memory;
- 4) present this information in visual form for local monitoring.

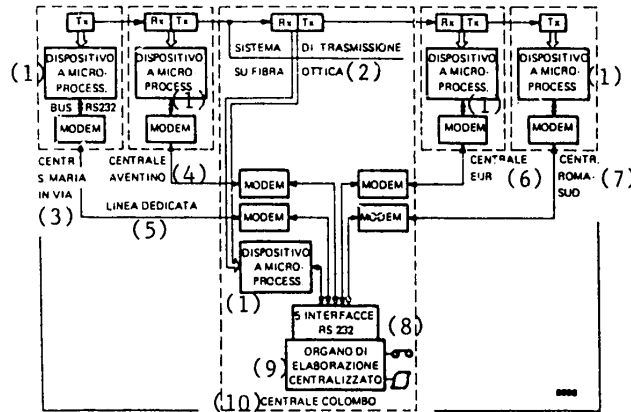


Figure 7. Block diagram of the measurement-data acquisition and processing system of the COS 3/FOSTER experimental installation

## Key:

- |                                      |                                 |
|--------------------------------------|---------------------------------|
| 1. Microprocessor device             | 6. EUR center                   |
| 2. Optical-fiber transmission system | 7. Rome-South center            |
| 3. Santa Maria in Via center         | 8. 5 RS-232 interfaces          |
| 4. Aventino center                   | 9. Centralized processing organ |
| 5. Dedicated line                    | 10. Colombo center              |

The device in question is inserted into a measurement-data acquisition and processing system, the block diagram of which is given in Figure 7 and that has the purpose of monitoring the performance characteristics of the COS 3/FOSTER experimental digital-transmission systems installed on optical cable between the Sanata Maria in Via and Rome-South exchanges, in Rome (Bibliography 3, 4, 5).

Because of the experimental aspect of the installation, it is necessary to relate the deterioration of transmission quality to the course of the performance characteristics of the principal system components to be monitored.

It is therefore necessary for the microprocessor to take, at regular time intervals, a certain number of digital and analog magnitudes that characterize the systems' transmission and reception terminals and store them in memory.

The magnitudes to be memorized for each transmission system are the following:

- 1) number of erroneous bits within a suitable time window;
- 2) alarms of the receiving and transmitting terminal and power-supply alarms;
- 3) pilot current of the LED (Light-Emitting Diode) in the transmission terminal;
- 4) temperature of the LED container in the transmission terminal;
- 5) current of the AGC (Automatic Gain Control) reaction ring in the reception terminal;

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6) polarization voltage of the APD (Avalanche Photodiode) in the reception terminal.

The microprocessor assigns a sequential number to each data block, consisting of the abovementioned magnitudes relative to all the systems monitored, and in addition, calculates for each system the EFT\*--a magnitude very significant for establishing, together with the error rate,\*\* the quality of the transmission.

All these parameters characterize, for the time-interval considered, the state of the transmission systems being monitored, and they constitute the data block that will be sent to the centralized processing organ on its request.

The centralized processing organ synchronizes the individual microprocessors and periodically issues to them the order to send the last block memorized. In this way, it is capable of deducing the cause of any deterioration of transmission quality.

The error rate is checked as follows: when the centralized processing organ perceives that it has gone beyond preestablished thresholds, it memorizes on magnetic support the "history" of the transmission system whose quality has deteriorated. These measurement data are printed out and can be processed off-line to determine any eventual functions of statistical distribution of the errors.

The measurement-data acquisition and processing system described is thus a typical example of a distributed-intelligence system; indeed, some of the functions to be performed have been assigned to the peripheral microprocessors. In this way, the following advantages over a completely centralized structure were obtained:

- a) greater processing speed;
- b) greater flexibility of the structure;
- c) increase in overall reliability of the system.

The microprocessor also performs the function of local monitoring of transmission systems: all the magnitudes stored in memory can in fact be visualized on a screen and the local operator is therefore enabled to perceive any malfunctions of the systems being monitored or deterioration of transmission quality.

## 6. Outlooks and Conclusions

The continual technological evolution in the field of integrated circuits opens up new prospects for the users of these devices. There are essentially two lines of approach identifiable in the construction of microprocessors apparatuses for transmission systems:

- a) In the cases in which these apparatuses have to process the signal in real time, the approach is to individuate very specific functions of the transmission system

---


$$* \text{ EFT} = \frac{\text{minutes without error}}{\text{minutes of observation}}$$

$$** \text{ error rate} = \frac{\text{number of erroneous bits}}{\text{number of bits received}}$$

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(for example: filtering, coding) and develop them with microprocessors specialized for such applications, which make possible a speed of treatment of the input symbols of some 10's of kHz.

If it is necessary to increase the input-symbol processing speed beyond that limit, the approach expected is to design ad-hoc (custom) integrated circuits. Such a choice entails an integration of the tasks of the custom-circuit designer and of the person who defines the architecture of the system to be integrated.

b) In those cases in which the microprocessor apparatuses are intended to have system management or control functions, the approach is to use "single chips" in the minimal applications and 16-bit microprocessors when the data-processing problem is complex. In both cases, the approach is to distribute the processing capacity in peripheral equipment, when the action of the control or management system has to extend over a broad territory.

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ITALY

DIGITAL RADIO-RELAY SYSTEMS AT 19 GHz IN URBAN AREAS

Turin ELETTRONICA E TELECOMUNICAZIONI in Italian Nov-Dec 81 pp 247-252

[Article by P. Amadesi, R. Failli, G. Masone and L. Moreno\*]

[Text] Summary--Digital radio-relay systems operating at 19 GHz for metropolitan areas. In the near future, digital radio-relay links should connect telephone exchanges in metropolitan areas. The main problems related to the design and development of such systems are considered and some proposed solutions are discussed. First, the general system characteristics are dealt with and the choice of the 17.7 to 19.7 GHz band is justified, taking into account the expected hop length, link capacity, availability required, etc. The criteria for an efficient spectrum utilization are next examined. The four-phase PSK seems to be the most feasible because it represents the best compromise between bandwidth occupancy and interference sensitivity in a multiple interference environment. Moreover, an effective procedure for automatic carrier frequency assignment has been adopted in order to minimize the number of radio channels required. Finally the compatibility with satellite systems sharing the same frequency band is discussed and some preliminary results on coordination procedures are presented.

1. Introduction

The link network that connects urban telephone exchanges has until now used almost exclusively paired cables installed in conduit.

In recent years, though, digital systems on cable have been introduced especially for the longer links, where they offer the greatest advantages from the technical and economic point of view. The introduction of digital-type exchanges will broaden the field of application of such systems, while in the future, optical-fiber cables will also be used in the same type of network.

The digital radio-relay systems are a valid alternative or a complementary means in this field of application, and they offer the following advantages:

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Typescript received 29 July 1981.

This paper was presented to the International Conference on Communications, 1981.

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- possibility of improving network availability by adopting diversified means of transmission (cable and radio) that are subject to breakdowns that have practically no correlation with one another;
- possibility of making inexpensive relay links in areas of difficult topography;
- possibility of making urgent connections in a short time.

Furthermore, cost comparisons have shown that medium- and high-capacity radio systems are suitable, as against coaxial-cable systems, for connections longer than about 2 km (Bibliography 1).

The introduction of radio-relay systems into this new field requires a detailed examination of various questions.

The purpose of the present paper is to provide a concise description of the main problems to be tackled in the design and development of the new radio systems to be used in urban relay networks, illustrating also the principal solutions adopted.

Section 2, in particular, presents the characteristics of the system anticipated for the 17.7-19.7 GHz band. In section 3 are discussed the criteria for efficient utilization of the spectrum within the urban environment, and an automatic procedure for assignment of frequencies in a close-mesh radio network is cited. Section 4 examines the problem of the sharing of the 17.7-19.7 GHz band as between radio relays on land and fixed services via satellite.

## 2. Characteristics of the System

In order to define the principal characteristics of the radio equipment to be used in the urban environment, and in particular the frequency band, the modulation method and the capacity per carrier, it is necessary to determine sufficiently closely the network configuration, the distribution of the hop lengths and the number of circuits to be transmitted on each run.

As the first step, the visibility conditions between the urban telephone exchanges in the major Italian cities, both with a direct connection and through intermediate centers, including the existing radio stations, were checked. The height of the trestlework possibly necessary for achieving the visibility conditions was assumed to be limited to reasonable values, in order to respect the cities' environmental and esthetic requirements.

Next, the complete configurations of the networks were determined, taking into account both the visibility conditions and the preliminary assumptions relative to the breakdown, as between cable systems and radio systems, of the digital relay systems anticipated in the next 20 years. In particular, it was assumed that the minimum run length would be limited to 1.5 km and that connections would not be made with more than 4 runs.

As an example, Figure 1 shows the network configuration planned in the metropolitan area of Rome; for each run, the capacity, expressed in number of 35.368-Mbit/s systems (the third level of the European digital hierarchy), is indicated.

The final configuration of each urban network will necessarily depend on more precise technical and economic considerations, including overall network availability,

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that will be possible only after an adequate period of experience with systems in use. Nevertheless, the preliminary results already obtained are sufficient for optimizing the principal characteristics of the system.

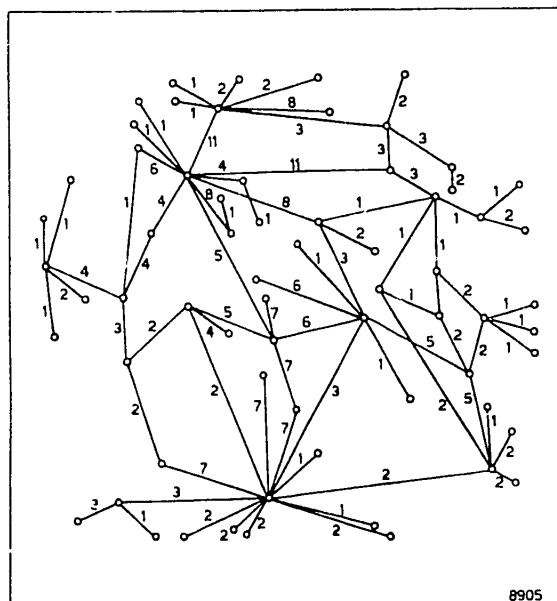


Figure 1. Digital radio-relay network at 19 GHz planned in the area of the city of Rome for the year 2000. The number marked on each run is the number of 34-Mbit/s groups required for the run.

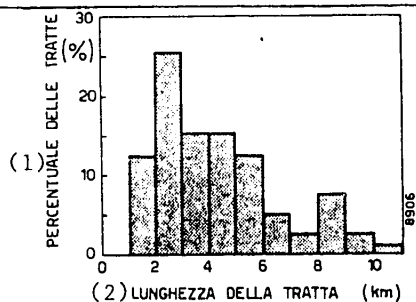


Figure 2. Distribution of the run lengths

Key:

1. Percentage of the runs      2. Length of run (km)

First of all, two radio-channel capacity values were chosen: 34 Mbit/s and 140 Mbit/s. It should be kept in mind that in the network planned for the urban area of Rome, which will certainly be one of the biggest ones, the number of 34-Mbit/s systems required for each run is between 1 and 11, and the percentage of runs that require at least eight 34-Mbit/s systems, which would justify a digit speed of 280 Mbit/s, is very low.

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Figure 2 presents a histogram of the distribution of the run lengths; it can be noted that the maximum length is approximately 10.5 km and that most of the runs are shorter than 6 km.

In order to keep the unavailability times due to rain below reasonable limits (10 to 20 prime minutes per year) for each of the runs, using normal fading margins on the order of 40 dB, it emerges that Italy's climatic conditions do not permit the use of bands higher than about 20 GHz (Bibliography 2). On the other hand, it is not suitable to use frequencies lower than 13 GHz, which would make it possible to have longer run lengths, since they are already assigned and used for medium- and long-distance connections.

A further requirement of the systems under consideration is that a rather high total radio band be available in order to meet the capacity requirements of the nodes in which many runs converge. The 17.7-19.7 GHz band therefore appears the most suitable for this type of application.

The ICCR [International Consultative Committee on Radiotelegraphy] recently approved the provisional text of a new recommendation relative to the plans for channelization of this frequency band for radio-relay systems with capacity of about 280 Mbit/s, 140 Mbit/s and 34 Mbit/s (Bibliography 3). The plans recommended for the configuration with cochannel reuse of frequencies for the capacities of 140 Mbit/s and 34 Mbit/s are shown in Figure 3.

As regards the modulation techniques, the considerations set out in section 3 in relation to dense radio networks indicate that four-phase PSK [expansion unknown] is the most suitable technique for the application examined in this paper.

The radio-relay systems that operate at lower frequencies generally adopt some form of protection (for example, difference of frequency or of spacing) in order to reduce the effects of the phenomena due to propagation and to improve the availability of the system as regards equipment breakdowns also. In the 17.7-19.7 GHz band, attenuation from rain is the dominant effect of propagation because of the limited lengths of the runs, and therefore it is not possible to improve the system's availability due to the propagation factors except by careful choice of the run lengths and of the fading margins.

For these reasons, use of protection systems of the 1 + 1 type or the multiple-beam type could only improve availability as regards equipment breakdowns.

In applications in urban areas where there is generally a diversified transmission medium, such as a cable network, it appears more appropriate to use unprotected systems, with consequent economic and spectrum-use advantages. The equipment must, of course, be protected with sufficient reliability to obtain availability of the connections similar to that of the cable systems.

Table 1 presents the typical values of the parameters relative to the equipment and the radio runs. In runs longer than 6 km, antennas of greater diameter (1.5 m) will be used in order to augment the fading margin available.

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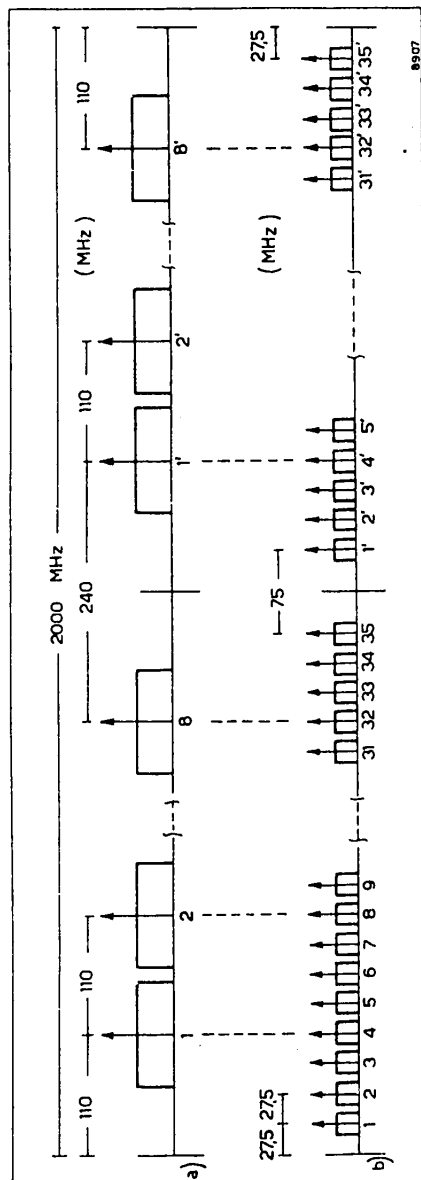


Figure 3. Channelization plan recommended by the ICCR for the 17.7-19.7 GHz band and for the speeds of 140 Mbit/s (upper) and 34 Mbit/s (lower). It is planned to use the same carrier frequencies as in the figure, with both horizontal polarization and vertical polarization.

Table 1 - Typical Parameters of the System

Frequency band	17.7-19.7 GHz
Modulation technique	4 PSK
Transmission speed	34 Mbit/s 140 Mbit/s
Output power of transmitters	+ 16 dBm + 22 dBm
Receiver input power for error probability = $10^{-3}$	- 79 dBm - 73 dBm
Gain of antenna (diameter = 1 m)	42.5 dB
Losses of branching circuits and of antenna power-supply circuits	6 dB
Fading margin for a 6-km run	40.5 dB

### 3. Criteria for Utilization of the Spectrum

In a radio-relay network of the type proposed in the preceding paragraphs, the interferential environment is quite different from the one common in conventional systems (long- or short-distance connections) (Bibliography 4).

In order to obtain high utilization of the spectrum, intensive frequency reuse is required, and consequently there will be multiple interferences on each connection (Bibliography 5, 6). Appropriate calcu-

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lation procedures have been developed for fast and accurate evaluation of the deteriorations of PSK signals in a multiple-interference environment (Bibliography 7).

In the preliminary phase of system definition, it was sought to evaluate the influence of various design parameters on utilization of the spectrum, by means of a generalized model based on the criteria and fundamental definitions of spectral efficiency (Bibliography 8).

The basic concept is that each radio connection, operated on a given frequency, prevents other connections from operating on that same frequency within a given region, which depends on the transmitting power, the antenna patterns, the propagation characteristics, the demodulator's sensitivity to interferences, etc.

Taking into account the fact that the radio spectrum can be defined in the three dimensions of frequencies, physical space and time (Bibliography 8), one can evaluate the "quantity of spectrum (band X area X time) used" by any connection of the network. Finally, the efficiency of utilization of the spectrum can be expressed as the ratio between the quantity of information transmitted on a given connection and the spectrum used by that connection.

In a previous article (Bibliography 9), a detailed description was given of the model adopted. Below, several results are presented relative to the choice of modulation method in digital radio-relay networks at 19 GHz.

### 3.1. Examination of Modulation Methods

The analysis model for utilization of the spectrum was applied vis-a-vis coherent PSK modulation systems with M phases. It is known that with the increase of M, the band occupied reduces, at equal transmission speed in terms of bit/s; nevertheless, with increase of M a more limited number of frequency reuses is acceptable, since sensitivity to interferences rises.

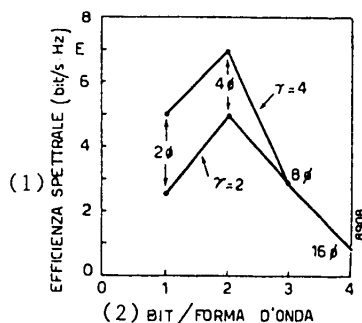


Figure 4. Efficiency of utilization of spectrum in a radio network with PSK modulation with M phases. On the abscissa is the number of bits associated with each wave form.

Key:

1. Spectral efficiency (bit/s · Hz)      2. Bit/wave-form

Figure 4 presents, for various values of M, spectral efficiency E, which is equivalent to the traffic capacity per band unit (bit/s·Hz) in a region of area equal to

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the mean quadratic value of the run length. Reference is also made to a parameter  $\gamma$ , which is indicative of the network density and is defined as follows:

$$\gamma = 2N \frac{\text{Mean quadratic value of run length}}{\text{Total area covered by radio network}}$$

in which N is the number of radio centers in the network.

Analysis of several actual cases has shown that  $\gamma = 2$  and  $\gamma = 4$  can be taken as representative values for urban networks of medium and high density, respectively.

The results of Figure 4 are based on the following hypotheses:

Transmission power	equal on all runs
Performance-characteristics threshold	error probability = $10^{-3}$ with 40 dB fading margin
Antenna pattern (diameter of paraboloid = 1 m)	ICCR mask (Report 614) with gain of 42.5 dB
Performance-characteristics deterioration from total of interference	3 dB ( X = 1.6 PSK 2 and 4 phases ( X = 2.0 PSK 8 phases ( X = 2.3 PSK 16 phases
Standardized channelization pitch	( frequential iso PSK 2 and 4 phases ( interstitial* PSK 8 and 16 phases
Frequency reuse on cross-polarization	
Parameter of density	$\gamma = 2$ and $\gamma = 4$

Various other calculations were carried out, with different sets of parameters, in order to check, in the various cases, the best compromises for optimal use of the spectrum. In any case, Figure 4 can be considered quite significant. It shows that 4-phase PSK modulation can be advised in this kind of application inasmuch as it achieves the best compromise between band occupation and sensitivity to interferences, in a broad range of real situations.

On the other hand, 2-phase PSK is the most efficient in very crowded networks and/or with antenna patterns that are not very directional. Eight-phase PSK, or other multilevel modulations of high order, may be preferable when limited band occupation becomes the dominant factor of spectral efficiency--that is, in low-density networks, such as the long-range ones.

### 3.2. Assignment of Transmission Frequencies

In the designing of a specific radio network, spectral efficiency can be optimized by careful coordination of the interferences. Since the number of connections may be very high, it is advisable for the assignment of the transmission frequencies to each run to be done by means of an automatic procedure.

The procedure described in Bibliography 10 meets this requirement, assigning the frequencies with the restriction of not exceeding a maximum level of interfering

\* In the case of frequency reuse with interstitial method, it is intended that the carrier frequencies on horizontal and vertical polarization be staggered by one-half a channelization pitch.

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power in each receiver and with the objective of minimizing the total number of carrier frequencies necessary in the entire network. The main advantage of this procedure is represented by the possibility of easily imposing various restrictions and of handling connections both of 34 Mbit/s and of 140 Mbit/s.

In the system-definition phase also, this procedure can be useful for analyzing the influence that various parameters (transmission power, antenna patterns, fading margins) have on the number of carrier frequencies required.

Several preliminary tests of this procedure were carried out, using a network with topological characteristics similar to those expected in the major Italian cities (see section 2). These tests have confirmed the validity of the frequency-assignment procedure and the possibility of intensive frequency reuse.

It was also verified that the number of carrier frequencies required depends considerably on the choice of the transmission powers and the fading margins. Consider, for example, the two cases presented in Table 2. In the first case, it is assumed that the power transmitted and the fading margin are fixed independently of the run length, while in the second, the power transmitted in the shorter connections (under 4 km) is considered reduced by 6 dB, so as to reduce overall interference. In the shorter connections, it is also assumed that there is a reduced fading margin, but nevertheless one that is sufficient to ensure the availability required (Bibliography 2).

Table 2--Parameters Adopted for Automatic Assignment of Carrier Frequencies

Digit Frequency	Hypothesis A		Hypothesis B		
	Transmitted Power	Fading Margin	Run Length	Transmitted Power	Fading Margin
34 Mbit/s	16 dBm	40 dB	≤ 4 km	10 dBm	35 dB
			> 4 km	16 dBm	40 dB
140 Mbit/s	22 dB	40 dB	≤ 4 km	16 dBm	35 dB
			> 4 km	22 dBm	40 dB

In the second case, it emerges that the necessary number of carrier frequencies is 25-percent less than in the first case. At present, other possible choices of transmitted power are being considered, keeping in mind the restrictions imposed by the simplicity required for the operations of tuning and maintaining the equipment.

The abovementioned calculations were done with adoption of the antenna-directionality mask proposed in ICCR Report 614 and assuming a 1-meter diameter of the paraboloid antenna. This mask was used merely as the first point of reference, while further calculations are planned that will use the radiation patterns of antennas designed for these applications.

#### 4. Sharing of Frequencies with Fixed Services via Satellite

The possible presence of fixed services via satellite that share the entire 17.7-19.7 GHz band, or part of it, with the fixed services on land, with primary-level allocation, is a fundamental problem to be examined for correct planning of a radio-relay network in an urban area.

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In the first place, the antennas' transmissions adhere to appropriate restrictions in ICCR Recommendations 358-2 and 406-4, so as to limit direct interference from space transmitters in the ground receivers and from ground transmitters in the space receivers.

Furthermore, the possible coexistence of radio-relay systems and earth stations receiving or transmitting from a satellite in a common geographical area requires that the mutual interferences be analyzed carefully, for correct coordination of the services.

We illustrate several preliminary results relative to this question, obtained from from the case of two satellite systems that are being planned in Italy.

a) The first problem examined concerns the earthward connection of a national satellite for telephonic communication with spot-beam coverages (Bibliography 11, 13) of the nation's major cities. The connection planned for the satellite-to-earth run uses the 17.7-20.2 GHz band and transports high-capacity channels. The earth stations receiving from the satellite must necessarily be situated within the metropolitan areas or in the immediate vicinity in order to be connected easily with the principal telephone-traffic switching centers. Consequently, all the radio channels via satellite that are not comprised within the 19.7-20.2 GHz part of the band (which are assigned exclusively to service via satellite) undergo the interferences caused by the urban radio relays.

For an initial quantitative evaluation of this interference, we established conservative hypotheses, assigning to the various parameters the numerical values given in Bibliography 11, considering the antenna radiation pattern of ICCR Report 390-3 for the earth-station antennas and examining the radio channels interfered with in the most unfavorable way.

The calculation results relative to the interference of a single transmitter of the radio-relay network in an earth station receiving from satellite are presented in Figure 5 in the form of "interference contours" on a topographical map. Each contour is characterized by a constant value of the gain  $G_R$  of the radio-relay antenna in the direction of the earth station (ES) and represents the total of the minimum distances around the ES in which a network transmitter with antenna gain  $G_R$  can be sited in such a way that the C/I ratio at the earth-receiver input is equal to 35 dB.

C/I is the ratio between the powers of the useful signal coming from the satellite in the severe fading conditions that cause the threshold condition of error rate of  $10^{-3}$  and the power of the nonfaded network interfering signal.

The 35-dB value of C/I is rather protective in a case in which there is only one interfering signal, and proves not very severe even if the radio network is dense; for example, 10 interfering signals with /equal frequency/ and with C/I = 35 dB each cause a total C/I ratio of 25 dB, which is therefore responsible for a considerable deterioration of the receiver's performance characteristics.

Figure 5 shows that the distance required for limiting the interference from a single transmitter is a notable function of antenna gain  $G_R$  and unfortunately can have values of several 10's of kilometers. Consequently, when the number of interfering transmitters of the network is high, the possible inclusion of stations re-

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ceiving from the satellite to earth in an urban area of medium extent appears rather critical.

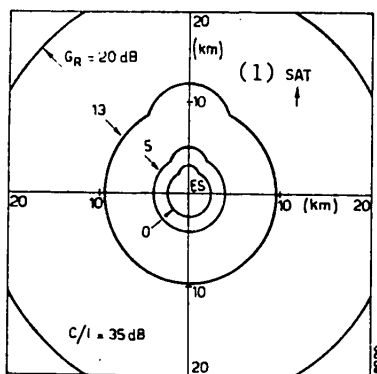


Figure 5. Sharing of frequency with the downward run of a national satellite for digital fixed services. Contours of interference in the case of a receiving earth station (ES) and an earth radio-relay transmitter with antenna gain  $G_R$  in the ES direction.  $C/I = 35$  dB. The satellite's angle of elevation is  $40^\circ$ , a value typical for Italy.

Key:

1. Satellite

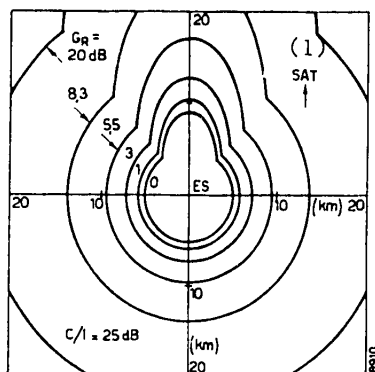


Figure 6. Sharing of frequency with the upward connection of a television-broadcasting satellite. Contours of interference in the case of a transmitting earth station (ES) and an earth radio-relay receiver with antenna gain  $G_R$  in the ES direction.  $C/I = 25$  dB. The television satellite's angle of elevation is  $30^\circ$ , a value typical for Italy.

Key:

1. Satellite

Assignment of the largest possible number of separate carrier frequencies to the two services therefore appears to be a requirement for reducing the complexity of coordination of the services.

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b) The second problem concerns the earth-satellite connection (feeder link) for direct broadcasting of television signals that could operate in the 17.3-18.1 GHz band and therefore share the spectrum portion between 17.7 and 18.1 GHz with the other fixed services.

In the Italian case, the five channels assigned to Italy and to the Vatican will probably fall within the sharing band (Bibliography 12), so that the power emitted from the transmitting earth station will cause interference in every earth receiver operating on those frequencies.

The possibility of siting the earth transmitting station within the metropolitan area has been examined with the aid of the interference contours of Figure 6, obtained in a manner analogous to those for Figure 5.

It was assumed that the EIRP (Effective Isotropic Radiated Power) of the earth station in the direction of the satellite is equal to 65 dBW and that the transmitting antenna has a diameter of 5 m radiation pattern in conformity with the ICCR characteristic (Report 390-3); the curves relate to the most severe interferential situation caused by the TV/FM channel most unfavorably positioned in relation to a 34-Mbit/s digital channel.

In Figure 6 there is only one source of interference--that is, the earth transmitting station--and the C/I ratio is therefore fixed at the critical value of 25 dB.

The situation certainly appears more severe than in the preceding case of Figure 5, and topological coordination of the two services proves quite complex in those cases in which the metropolitan network is rather dense.

Coordination of the ground services and those via satellite therefore constitutes an open problem that calls for further investigation in depth. More detailed and closer analysis of the interferences examined in this section was subsequently undertaken and is reported in Bibliography 14.

Acknowledgements

The authors thank Mr L. Bassis and Mr M. Ercolin for their effective cooperation in carrying-out of this work.

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